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Sawmill and Logging Residues from Ponderosa Pine Trees in the Black Hills

E. F. Landt and R. O. Woodfin, Jr.[1]

Sawmill and logging residues are an important source of raw material in the Black Hills. The material has been of little value locally in the past, however, because of lack of markets. The increasing use of sawmill residue for pulpwood has brought the Black Hills supply into the focus of the Lake States pulp and paper industry. This increase in interest brought with it the need for an accurate determination of the amounts and kinds of residues available for use, from both logging and milling. A previous study provided information on the proportion of a log that ends up as residues, but it did not provide information on the entire tree.[2] Therefore, the study reported here was undertaken to include the logging aspects, and in general arrive at the portion of the tree that ends up as lumber, and that which becomes residue.

This investigation required that both logging and milling residues be measured so that a complete accounting of what happens to a tree could be made. The entire stem of the sawtimber trees from stump to a 4-inch top, excluding the limbs, was measured. Residue conversion factors were computed for "putting the tree back together again," and for determining the volumes of the various kinds of residues that resulted during processing, from the woods to finished lumber.

METHODS

Logging residues were measured on 300 trees; 50 trees were selected at random on each of six different logging operations. The 300 trees were selected along a line from the stream bottom to the ridgetop to include variation in tree form due to site. Each tree was measured and scaled after it had been felled and bucked, but before the logs were skidded. Log bucking was not controlled but taken as normal practice. Total tree height to 8-inch (sawtimber minimum top, d.i.b.) and 4-inch (pulpwood minimum top, d.i.b) tops, and measurements of logs, tops, and cull logs were identified by individual tree (fig. 1). Diameter and length were measured on each log of the tree for cubic foot content determinations by Smalian's formula. Logs were scaled by the Scribner Decimal C Log Rule. Separate measurements were made to determine the volume

[1] *Technologists, located at Rapid City, in cooperation with South Dakota School of Mines and Technology; central headquarters are maintained at Fort Collins, in cooperation with Colorado State University.*

[2] *Kotok, E. S. An estimate of residues at a small sawmill in the Black Hills. U. S. Forest Serv. Rocky Mountain Forest and Range Expt. Sta. Res. Note 17, 6 pp., illus. 1955.*

of the tops included in the portion of the tree from the 8-inch point to the 4-inch point.

The ovendry weight of each log, tree top to a 4-inch d.i.b., and cull log, was computed by multiplying cubic foot content by 24.1 pounds per cubic foot, the average ovendry density of Black Hills ponderosa pine.[3] The weight of the bark on logging residues was computed with a factor of 11 percent bark weight per rough green cord.[4]

These weights and the net log scale of trees were used to determine logging residue conversion factors in terms of ovendry tons per M b.m. net log scale.

Sawmill residues were measured at six sawmills with circular headrigs. Two of the mills did not have resaws, two had cant sash gang resaws, and two had horizontal band resaws. A total of 277 logs were sampled from logs available at the six mills. At each mill the logs were selected by diameter and length classes from both sound and defective logs (logs with scalable defect):

Mill type	Sound logs	Defective logs	Total
No resaw	39	39	78
Horizontal band resaw	50	53	103
Cant sash gang resaw	45	51	96
Total	134	143	277

Log diameter ranged from 7 to 21 inches and length ranged from 12 to 16 feet for both sound and defective logs.

All sample logs were debarked by hand (fig. 2); the bark from each log was weighed separately. Samples of bark were ovendried to determine moisture contents for converting the total green bark weight to an ovendry weight.

The logs were sawn into 4/4 lumber according to commercial practice. Rough green lumber, slabs, edgings, rough trim, and cull lumber were each weighed separately (fig. 3). The green weights of these for each log were converted to ovendry weights by use of moisture contents of heartwood and sapwood previously determined for each log. The ovendry weight of sawdust was determined by subtracting the ovendry weight of the lumber, slabs, edgings, rough trim, and cull lumber from the total ovendry log weight.

Sawmill residue conversion factors for each log were expressed in ovendry tons per M b.m. rough lumber tally.

[3] *Drow, J. T., Dohr, A. W., and Bellosillo, S. Mechanical properties of ponderosa pine from the Black Hills. U. S. Forest Serv. Forest Prod. Lab. Rpt. 2090, 18 pp., illus. 1957.*

[4] *Landt, E. F., and Woodfin, R. O., Jr. Pulpwood characteristics of Black Hills ponderosa pine. Tappi, 42 (10): 809-812, illus. 1959.*

Figure 1.--Measuring top of a ponderosa pine sawtimber tree for cubic foot determinations.

Figure 2.--Bark, removed by hand at the sawmill, was collected and weighed separately.

Figure 3.--Chippable residues in the form of slabs, edgings, trim, and cull lumber from each log were weighed separately.

Planer mill residues consisting of dry shavings and dry trim were determined by measurements on 100 boards at each of five mills. Twenty-five 16-foot boards were selected from each 4-, 6-, 8-, and 10-inch width class. Each board was weighed before and after surfacing, but before trimming, to isolate the weight of shavings. Next the dry trim was collected and weighed. Moisture contents of the boards, determined by a moisture meter, were used to convert the weight of shavings and trim to an ovendry weight. Conversion factors for shavings and surfaced trim were expressed in ovendry tons per M b.m. rough lumber.

RESULTS

Logging residues.--Conversion factors for tops left in the woods, cull logs, and bark averaged 0.3215, 0.3918, and 0.0678 ton per M b.m. net Scribner log scale, or 0.2776, 0.3383, and 0.0585 ton per M b.m. rough lumber tally, respectively.

Actual volume of tops left in the woods averaged 4.65 cubic feet per tree, and by logging area ranged from an average of 2.92 to 9.08 cubic feet per tree (table 1). The volume of tops between the 8-inch point and the 4-inch point averaged 3.08 cubic feet per tree, and by logging area ranged from an average of 2.60 to 3.53 cubic feet per tree (table 1).

Table 2 shows the average cubic foot volume of tops for trees by d.b.h. For example, a 9-inch tree averaged 5.65 cubic feet of tops (8-inch d.i.b. to 4-inch d.i.b.) whereas a 20-inch tree averaged 1.90 cubic feet of tops.

Sawmill residues.--The original intention was to obtain a regression of each yield residue per M b.m. on log diameter at each mill type from the sample log data for sound and defective logs separately. The frequency distribution of log diameters in the population,

Table 1.--Volume of tops in Black Hills ponderosa pine sawtimber trees on six logging areas (50 trees from each area)

Logging area	Average d.b.h.	Scribner log scale per tree		Scalable defect	Average volume of tops per tree			
		Gross	Net		8- to 4-inch d.i.b.		Left in woods	
	Inches	Bd.ft.		Percent	Cu.ft.	Cords[1]	Cu.ft.	Cords[1]
Benchmark	15.7	202	174	13.9	3.53	0.0465	4.45	0.0586
Redbird	16.4	250	102	59.2	2.60	.0343	9.08	.1196
Bobcat	17.1	293	264	9.9	2.95	.0389	3.78	.0498
Iron Creek	14.4	201	160	20.4	3.31	.0436	3.91	.0515
Lost Gulch	14.5	155	116	25.2	3.18	.0419	2.92	.0385
Norris Peak	17.9	281	230	18.2	2.92	.0385	3.75	.0494
Average	16.0	230	175	23.9	3.08	.0406	4.65	.0612

[1] 75.9 cubic feet in a standard rough cord (see text footnote 4).

Table 2.--Volume of tops in Black Hills ponderosa pine trees between 8 inches d.i.b. and 4 inches d.i.b. (Basis: 300 trees)

D.b.h.[1] (inches)	No. of trees	Volume of tops per tree		
		Raw data	Curved data[2]	
		Cu.ft.	Cu.ft.	Rough cords[3]
9	1	5.65	5.46	0.0719
10	12	4.75	4.95	.0652
11	21	4.59	4.46	.0588
12	35	3.98	3.98	.0524
13	32	3.58	3.58	.0472
14	36	2.98	3.16	.0416
15	28	2.79	2.90	.0382
16	31	2.39	2.65	.0349
17	19	3.00	2.43	.0320
18	25	2.38	2.25	.0296
19	17	2.21	2.10	.0277
20	8	1.90	2.00	.0264
21	12	3.28	1.89	.0249
22	7	2.31	1.78	.0235
23	7	1.87	1.70	.0224
24	2	1.33	1.64	.0216
25	2	1.03	1.57	.0207
26	3	2.10	1.50	.0198
27	1	1.27	1.44	.0190
28	0	--	1.39	.0183
29	1	1.40	1.34	.0177

[1] Inch classes; i.e., 10-inch class = 10.0-10.9.
[2] Curve fitted by hand.
[3] 75.9 cubic feet in a standard rough cord (see text footnote 4).

as obtained from a previous study,[5] would then be used with the regression to obtain a weighted residue estimate for the population. The analysis showed nonsignificant regressions for all residue items except slabs, which indicates that residue amounts could be considered independent of log diameter. The slab regressions showed significantly greater amounts of slabs from small logs at all mills, but were not particularly good for prediction purposes due to the large unaccountable error ($r^2 < 0.35$). The conversion factors were therefore obtained separately for sound and defective logs as a simple average of the individual logs for each mill type (table 3).

[5] *Landt, E. F., and Woodfin, R. O., Jr. Amounts and grades of lumber from Black Hills ponderosa pine logs. U. S. Forest Serv. Rocky Mountain Forest and Range Expt. Sta. Sta. Paper 42, 24 pp., illus. 1959.*

The defective logs without exception show larger conversion factors than the sound logs. This is not unexpected and is due to larger tonnage of residues from defective logs and lower yields of lumber. The precision of the results is adequate, with half width of the 0.95 confidence interval generally about 15 percent of the mean.

The weighted averages (table 3) were obtained by averaging sound and defective conversion factors with weights of 0.55 and 0.45, respectively, the relative rough lumber recovery volumes of sound and defective logs obtained from a previous study.[5]

Conversion factors for total sawmill residues (including bark) ranged from a low of 1.3601 tons per M b.m. of rough lumber, for gang resaw mills, to a high of 1.7398 tons per M b.m. for mills with no resaws. Also, the total residue conversion factor for the band resaw mills was near the high, at 1.6228 tons per M b.m.

Conversion factors for chippable residues --slabs, edgings, rough trim, and cull lumber--totaled 0.5782 ton per M b.m. at the gang resaw mills, 0.8265 ton per M b.m. at the band resaw mills, and 0.7047 ton per M b.m. at the mills with no resaws (table 3). Average factors for fine residues--sawdust plus bark--totaled 0.7818 ton per M b.m. for the gang resaw mills, 0.7963 ton per M b.m. for the band resaw mills, and 1.0349 ton per M b.m. for the mills with no resaws.

Sawdust was the largest single kind of residue produced at all the mills. An average of 0.7604 ovendry ton of sawdust was produced at the mills with no resaws for every 1,000 board feet of rough lumber cut (table 3). In contrast, the mills with gang resaws produced 0.5663 ovendry ton and the mills with band resaws produced 0.5024 ovendry ton.

Slabs accounted for the second largest amount of residue. At the mills with no resaws, 0.3880 ton of slabs was produced per M b.m. rough lumber, and 0.2914 and 0.3178 ton per M b.m. were produced at the gang and band resaw mills, respectively.

Table 3. --Conversion factors for residues at three types of circular headrig sawmills cutting 4/4 rough lumber from ponderosa pine in the Black Hills

Type of mill, condition of logs, and weighted averages	Chippable residues				Fine residues		Total all residues
	Slabs	Edgings	Rough trim	Cull lumber	Sawdust	Bark	
	Ovendry tons per M b.m. rough lumber tally[1]						
NO RESAW:							
Sound logs	0.3157 ± 0.0536	0.1470 ± 0.0318	0.0675 ± 0.0568	0	0.6425 ± 0.0660	0.2589 ± 0.0424	1.4316 ± 0.1144
Defective logs	0.4764 ± 0.1396	0.1730 ± 0.0288	0.1542 ± 0.0330	0.1144 ± 0.1260	0.9047 ± 0.2098	0.2937 ± 0.0444	2.1164 ± 0.4246
Weighted average[2]	0.3880 ± 0.0695	0.1587 ± 0.0217	0.1065 ± 0.0341	0.0515 ± 0.0567	0.7604 ± 0.1012	0.2745 ± 0.0307	1.7398 ± 0.2012
CANT SASH GANG MILLS:							
Sound logs	0.2467 ± 0.0428	0.1104 ± 0.0152	0.0862 ± 0.0266	0	0.4834 ± 0.0612	0.1909 ± 0.0216	1.1176 ± 0.0940
Defective logs	0.3461 ± 0.0572	0.1473 ± 0.0240	0.1831 ± 0.0394	0.0667 ± 0.0546	0.6677 ± 0.0826	0.2456 ± 0.0306	1.6565 ± 0.1890
Weighted average[2]	0.2914 ± 0.0349	0.1270 ± 0.0136	0.1298 ± 0.0230	0.0300 ± 0.0245	0.5663 ± 0.0501	0.2155 ± 0.0181	1.3601 ± 0.0995
HORIZONTAL BAND MILLS:							
Sound logs	0.2594 ± 0.0436	0.2531 ± 0.0416	0.1090 ± 0.0330	0	0.3992 ± 0.0596	0.2786 ± 0.0338	1.2993 ± 0.1414
Defective logs	0.3891 ± 0.0776	0.2881 ± 0.0426	0.1863 ± 0.0496	0.2136 ± 0.1550	0.6285 ± 0.1180	0.3125 ± 0.0470	2.0181 ± 0.3488
Weighted average[2]	0.3178 ± 0.0424	0.2688 ± 0.0298	0.1438 ± 0.0288	0.0961 ± 0.0704	0.5024 ± 0.0624	0.2939 ± 0.0282	1.6228 ± 0.1751

[1] 95 percent confidence limit.

[2] Weighted average obtained by averaging sound and defective conversion factors with weights of 0.55 and 0.45, respectively, the relative rough lumber recovery volumes of sound and defective logs obtained from a previous study (see text footnote 5).

Planing mill residues. -- The remaining residue category consists of shavings and dry trim. The conversion factor for shavings was found to average 0.3442 ton per M b.m., while that for dry trim averaged 0.0458 ton. No significant difference was found in amount of shavings and trim produced at the five different planing mills.

Relation of lumber recovery to residue. -- With reference to all mill types, from 56 to 60 percent of the tree ends up as sawing and planing residues, while 21 to 23 percent ends up as lumber (fig. 4). The remaining 19 to 21 percent ends up as logging residues. The mills without resaws converted more of the tree into sawmill residues (60 percent) and less into lumber than the mills with resaws. However, even sawmills with resaws yielded only 21 to 23 percent of the tree as lumber.

DISCUSSION

Results of residue measurements of Black Hills ponderosa pine sawtimber trees to a 4-inch top diameter showed that from 77 to 79 percent of the tree ends up as residues. Logging residues totaled 19 to 21 percent, while sawmill and planing mill residues totaled from 56 to 60 percent. Sawmills with conventional circular headrigs and without resaws produced from 1 to 4 percent more residues than did mills with resaws. This was due primarily to the greater amounts of sawdust at the mills without resaws. As can be seen in figure 4, most residues are produced at the sawmill.

Chippable residues make up from 18 to 24 percent of the tree. The total in form of slabs, edgings, rough trim, and cull lumber ranged from 0.5782 to 0.8265 ton per M b.m. rough lumber tally, whereas chippable logging residue in the form of tops and cull logs added an additional 0.6159 ton per M b.m. Sawmills would therefore have access to a total of from 1.1941 to 1.4424 tons of chippable material per thousand board feet rough lumber tally if all the residues could be debarked and assembled economically for chipping. Generally, chippable sawmill residues have a cost advantage because most of the cost of transportation and production has been paid for by the lumber. Results of this study showed that sawmills can expect to recover from one-half to two-thirds of a unit of chips (one unit = 2,400 pounds ovendry) for every 1,000 board feet of 4/4 lumber cut. These amounts are based on current utilization standards where the minimum top diameter saw log is 8 inches.

With the exception of slabs, log diameter did not affect the amount of residues per M b.m. produced at the three types of mills. Because the relation was weak, even for slabs, the means were used as conversion factors.

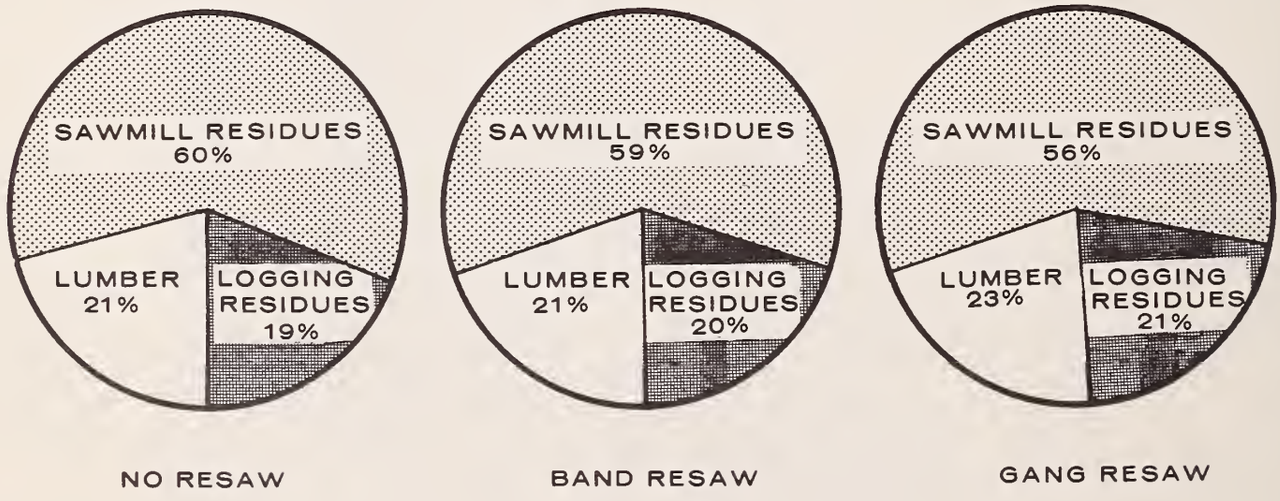

Figure 4.--Proportion of the tree (to a 4-inch top) in logging residues, sawmill residues, and lumber at three types of circular headrig sawmills.

Scalable defect in logs, however, did have a strong influence on residue yields. Generally, the amount of chippable residue produced from cutting 1,000 board feet of lumber from defective logs was double that from sound logs. Also, mill type influenced residue yields, especially sawdust. For example, the circular headrig mills without resaws produced the highest proportion of sawdust. Mills with resaws, where more of the lumber from a log was cut on thinner saws than the circular headrig, produced about 1,000 pounds of sawdust per M b.m. of lumber produced. In contrast, the mills without resaws, where all the log was cut into lumber on the circular headrig, produced about 1,500 pounds of sawdust per M b.m. of lumber.

To illustrate the magnitude of the amounts of residue produced in a normal lumbering operation, logging and sawmill residue weights were computed for a gang resaw mill cutting 30,000 board feet of rough green 4/4 lumber per day (table 4). This example shows that the gang resaw mill would produce 17.3 tons of ovendry chippable residues a day ($30 \times 0.5782 = 17.3$ tons) plus 18.4 tons of chippable material in the form of tops and cull logs in the woods ($30 \times 0.2776 + 30 \times 0.3383$). In addition, 35.2 tons of ovendry sawmill and planing residues would be produced in the form of sawdust, bark, shavings, and trim. Similar calculations can be made for mills without resaws or with a band resaw by using the residue conversion factors listed in table 3.

Table 4.--Estimated weight of ovendry logging and sawmilling residues from the production of 30 M b.m. of 4/4 ponderosa pine lumber by circular headrig sawmill with cant gang resaw

Product	Residue conversion factor	Total weight		
	Tons per M b.m. rough lumber tally	---- Tons ----		Percent
RESIDUES:				
Logging --				
Tops left in woods	0.2776	8.3		
Cull logs	.3383	10.1		
Bark	.0585	1.8		
Total			20.2	21
Sawmill--				
Chippable	.5782	17.3		
Sawdust	.5663	17.0		
Bark	.2155	6.5		
Total			40.8	43
Planing--				
Shavings	.3442	10.3		
Trim	.0458	1.4		
Total			11.7	13
All residues			72.7	77
LUMBER:				
Surface dry			21.6	23
Total			94.3	100

SUMMARY AND CONCLUSIONS

Results of measurements on 300 trees and 277 saw logs revealed that Black Hills ponderosa pine trees yield from 77 to 79 percent of the tree weight to a 4-inch top diameter in residues of various kinds. Only 21 to 23 percent ends up as lumber (fig. 4). These proportions of residues and lumber were determined by use of conversion factors developed for logging residues, sawmill residues, and planing residues for three kinds of circular headrig sawmills, and for both sound logs and logs with scalable defect.

The defective logs without exception showed larger conversion factors than the sound logs. Significant differences were also found between the conversion factors for the various kinds of sawmill residues produced at three types of circular headrig sawmills. For example, the largest amount of total residue was produced at sawmills with no resaws, but the largest amount of chippable residue was produced at the band resaw mills. Chippable residue yields ranged from one-half a unit at the gang resaw mills to two-thirds a unit at the band resaw mills.

The large volume of residues resulting from lumbering operations could form the basis for added income to mills if markets could be found. For example, assume a gang resaw mill cutting (from a random distribution of log diameters)[5] 30,000 board feet of 4/4 rough lumber per day. This mill would produce in total, 72.7 tons of ovendry residue and the surface dry lumber would weigh about 21.6 tons from the factor 0.7205 ton per M b.m. surface dry. The total residue would include 40.8 tons of sawmill residues, 11.7 tons of planing mill residues, and the harvesting of the logs would account for 20.2 tons of logging residues.

A strong demand for pulp chips could have a significant effect on the fuller utilization of Black Hills ponderosa pine sawtimber. If chipping sawmill and logging residues were found profitable, an additional 40 to 53 percent of the volume of the tree could be recovered. Several Black Hills mills have made a good start in this direction and are converting most of the sawmill and some logging residues into pulp chips. Therefore, these mills have an opportunity to use up to 59 to 64 percent of the tree, where before they were using only 21 to 23 percent.